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The increasing role of reverse total shoulder arthroplasty in the treatment of proximal humerus fractures

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ABSTRACT

Introduction: Hemiarthroplasty of the shoulder is a well established treatment for proximal humerus fractures not amenable to open reduction internal fixation. However, orthopedic surgeons have recently increased utilization of reverse total shoulder arthroplasty (RTSA) in the treatment of these injuries. The purpose of this study was to evaluate the use of hemiarthroplasty and RTSA between 2009 and 2016 for the treatment of proximal humerus fractures within a large United States integrated healthcare system.
Materials and methods: A descriptive study was conducted using our integrated healthcare system's Shoulder Arthroplasty Registry. Shoulder arthroplasty cases performed for an acute proximal humerus fracture between the years of 2009 and 2016 were identified. Revision rates were determined, as well as changes in age and gender distribution of the cohort during the study period.
Results: In 2015, RTSA utilization surpassed that of hemiarthroplasty for the first time in the healthcare system. The utilization of RTSA in the treatment of proximal humerus fractures increased from 4.5% of all arthroplasties in 2009 to 67.4% of arthroplasties in 2016. During the study period, patients undergoing hemiarthroplasty were younger and less likely to be female. Crude revision rate was 4.0% for hemiarthroplasty and 3.2% for RTSA.
Conclusions: RTSA is increasingly being utilized for the treatment of proximal humerus fractures and now appears to be the treatment of choice. While hemiarthroplasty appears to be falling out of favor in the treatment of fractures of the shoulder, surgeons may still be preferentially using the procedure in younger patients.

Introduction

Proximal humerus fractures are the third most common fracture in those over 65 years of age, behind the hip and distal radius [1]. There is general agreement that the overwhelming majority of these fractures can be treated nonoperatively. In unreconstructable fractures not amenable to open reduction internal fixation (ORIF), hemiarthroplasty is a long accepted treatment, especially in those with poor bone quality [2–6]. However, results of hemiarthoplasty in this setting are inconsistent with poor functional outcomes reported [7–11].

With expanding indications for reverse total shoulder arthroplasty (RTSA) since its approval by the United States (US) Food and Drug Administration in 2003, several recent studies have compared the results of RTSA with hemiarthroplasty for treating acute proximal humerus fractures [9,12–19]. One of the main theoretical advantages of RTSA in this setting is less reliance upon healed tuberosities and a functioning rotator cuff [13]. Results of RTSA used in fracture treatment are promising; a recent randomized controlled trial comparing RTSA and hemiarthroplasty for fracture in patients over 70 demonstrated better functional outcomes and fewer revisions with RTSA [17].

The purpose of this study was to evaluate the changing use of shoulder athroplasty for the treatment of acute poximal humerus fractures between 2009 and 2016 within a large US integrated healthcare system. Additionally, revision rates were determined, as well as changes in patient age and gender distribution of those undergoing shoulder arthroplasty during the same time period.

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Methods

Study design, setting, and data sources

We conducted a descriptive study using data from a large US integrated healthcare system's Shoulder Arthroplasty Registry (SAR). The integrated healthcare system serves over 12.2 million members in eight geographical regions of the US [20]. Health plan membership has previously been shown to be largely socioeconomically and demographically representative of the geographical areas it covers [21,22].

Details about data collection, protocols, coverage, and baseline cohort characteristics of the SAR have been previously published [23,24]. In brief, this registry collects information using electronic intraoperative data capture forms completed by surgeons, while additional data is pulled from electronic health records and adminstrative claims. Detailed information on the procedures performed, surgical indications, patients, implants, surgeons and hospitals involved with these procedure, as well as surgical outcomes are monitored by this registry. Outcomes are prospectively monitored using electronic screening algorithms which are then validated by trained clinical content experts.

Institutional Review Board approval was obtained prior to the inception of the registry.

Study population

Primary shoulder arthroplasty cases performed for the diagnosis of fracture between January 1, 2009 and December 31, 2016 were included. No revision cases were included in this cohort. Patients were included from all regions of the integrated healthcare system.

Exposure and outcome of interest

The exposure of interest was shoulder arthroplasty performed for an acute fracture, categorized as hemiarthroplasty or RTSA (the registry does not collect proximal humerus fractures treated with ORIF). Conventional total shoulder arthroplasty procedures were excluded (n = 4). All-cause revision was the primary outcome, defined as any operation after the index procedure in which a component was exchanged, removed, or added.

Covariates

Patient factors described included age (continuous, and categories: <55, 55–69, 70–84, and ≥85 years old), body mass index (BMI, continuous and categories <30, 30–35, ≥35), gender (female versus male), race (white, Hispanic, and other races), and American Society of Anesthesiologists (ASA) classification (1–2 versus ≥3). Procedural factors described included operative side (left versus right) and bilateral procedure (yes versus no).

Statistical analyses

Means, standard deviations (SD), frequencies and proportions were used to describe the study sample.

Change in patient demographics in terms of age and gender was assessed over time using the Kruskal-Wallis test for continuous variables and Fisher's exact test for categorical variables. Procedure-specific volume was determined. Lastly, the revision risk of RTSA and hemiarthroplasty was compared. Revision was modeled as a time-to-event outcome using Cox regression adjusted for age and gender. Patients were censored on the date of death, the date of healthcare plan membership termination, or the date of final registry surveillance for the study (31 December 2016), whichever came first. The proportional hazards assumption was checked. When the assumption was not met, which indicated the true hazards were changing at a different rate during the follow-up time, we modeled the effect as time-varying covariates. Missing data for age (n = 27) and gender (n = 27) were handled using mean imputations. Analyses were performed using R version 3.3.0 and alpha = 0.05 was the statistical significance threshold used for this study.

Results

Between January 1, 2009 and December 31, 2016, 971 hemiarthroplasty and 441 RTSA procedures were performed for acute proximal humerus fractures (Table 1). The number of patients undergoing hemiarthroplasty decreased during every year of the study period, ranging from a peak of 190 cases in 2009 (95.5% of arthroplasties) to 57 cases in 2016 (32.6% of arthroplasties). Likewise, the number of patients undergoing RTSA for fracture increased from 9 in 2009 (4.5% of arthroplasties) to 118 in 2016 (67.4% of arthroplasties) (Fig. 1).

In the 971 hemiarthroplasty procedures, the mean age was 69.4 (SD = 11.2) years and mean BMI was 30.6 (SD = 8.1). On a yearly basis, average age trended down ($p < 0.001$) from a peak of 72.9 years in 2009 to 63.8 years in 2016. Most patients were female (77.2%), white (80.3%), and had an ASA of 3 or higher (53.7%). Although the percentage of hemiarthroplasty patients that were female declined from 80.2% in 2009 to 68.4% in 2016, this finding was not significantly different across years ($p = 0.185$) (Table 2). More hemiarthroplasties were performed on the right extremity (53.3%) and bilateral procedures were uncommon (0.8%).

In the 441 RTSA procedures, the mean age was higher at 74.7 (SD = 8.6) years, while the mean BMI was 29.7 (SD = 6.9). Average age on a yearly basis flucuated during the study, ranging from a high of 79.2 years in 2012 to a low of 73.6 years in 2016, but the age distribution did not change ($p = 0.214$) (Table 2). Similar to hemiarthroplasty, most RTSA patients were female (84.3%), white (79.8%), and had an ASA of 3 or higher (66.9%). The primary operative side was also right (58.0%) and bilateral procedures were uncommon (0.9%).

When stratifying by age group, almost all procedures performed for acute proximal humerus fractures in patients less than 55 years of age were hemiarthroplasties (80 versus 4 RTSA). For all other age groups, the proportion of fractures where RTSA was performed increased each year observed. For patients aged 55–69 years, the proportion of RTSA performed compared to hemiarthroplasty rose from 3.5% in 2009 to 50.0% in 2016.

Table 1
Patient characteristics & demographics treated for shoulder fractures, 2009–2016.

Patient characteristics	Hemi (N = 971)	Reverse TSA (N = 441)	Combined (N = 1412)
Age, years. Mean ± SD	69.4 ± 11.2	74.7 ± 8.6	71.1 ± 10.7
<55	8.4%(80)	0.9%(4)	6.1%(84)
55-69	43.5%(414)	27.2%(118)	38.4%(532)
70-84	38.5%(366)	58.5%(254)	44.8%(620)
≥85	9.6%(91)	13.4%(58)	10.8%(149)
BMI: Mean ± SD	30.6 ± 8.1	29.7 ± 6.9	30.3 ± 7.7
<30	54.2%(510)	56.0%(239)	54.8%(749)
30-35	22.1%(208)	26.5%(113)	23.5%(321)
≥35	23.7%(223)	17.6%(75)	21.8%(298)
Gender: Female	77.2%(734)	84.3%(366)	79.4%(1100)
Race: White	80.3%(756)	79.8%(344)	80.2%(1100)
ASA: ≥3	53.7%(456)	66.9%(238)	57.6%(694)
Laterality: Right	53.3%(518)	58.0%(256)	54.8%(774)
Bilateral	0.8%(8)	0.9%(4)	0.8%(12)

Missing pattern: Age N = 27, BMI N = 44, gender N = 27, ASA N = 207.

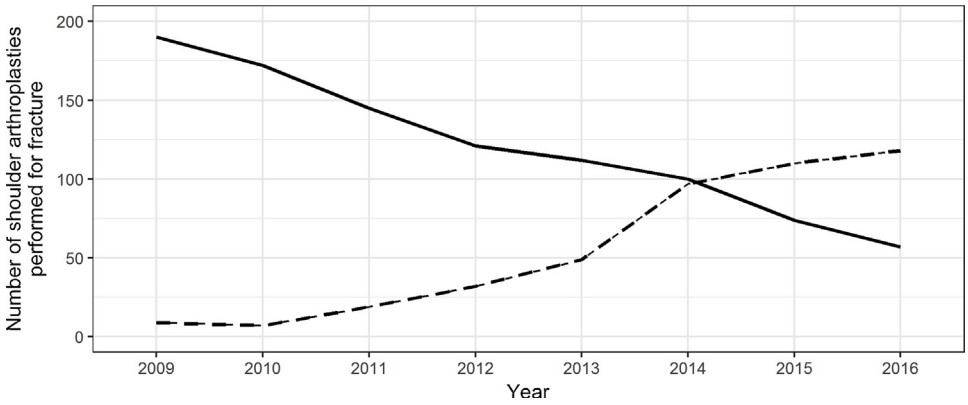

Fig. 1. Number of patients who underwent shoulder arthroplasty for the indication of fracture, 2009–2016. Hemiarthroplasty = solid line. Reverse TSA = dashed line.

Table 2
Patient demographics by surgery type 2009–2016.

Year Hemi	2009 (N = 190)	2010 (N = 172)	2011 (N = 145)	2012 (N = 121)	2013 (N = 112)	2014 (N = 100)	2015 (N = 74)	2016 (N = 57)	p*
Gender: Female	80.2% (150)	76.9% (130)	82.3% (116)	75.4% (89)	71.6% (78)	81.8% (81)	71.8% (51)	68.4% (39)	0.185[f]
Age, years. Mean ± SD	72.9 ± 10.8	69.9 ± 10.6	69.1 ± 11.2	69.4 ± 11.8	68.3 ± 9.8	68.8 ± 10.8	66.8 ± 12.9	63.8 ± 10.7	<0.001[k]
<55	4.8% (9)	7.1% (12)	10.6% (15)	6.8% (8)	8.3% (9)	8.1% (8)	16.9% (12)	12.3% (7)	<0.001 [f]
55-69	29.4% (55)	43.2% (73)	43.3% (61)	44.9% (53)	52.3% (57)	52.5% (52)	42.3% (30)	57.9% (33)	
70-84	51.3% (96)	40.8% (69)	36.9% (52)	35.6% (42)	34.9% (38)	29.3% (29)	33.8% (24)	28.1% (16)	
≥85	14.4% (27)	8.9% (15)	9.2% (13)	12.7% (15)	4.6% (5)	10.1% (10)	7.0% (5)	1.8% (1)	
Reverse TSA	**(N = 9)**	**(N = 7)**	**(N = 19)**	**(N = 32)**	**(N = 49)**	**(N = 97)**	**(N = 110)**	**(N = 118)**	
Gender: Female	88.9% (8)	85.7% (6)	78.9% (15)	90.6% (29)	89.6% (43)	82.3% (79)	86.9% (93)	80.2% (93)	0.677[f]
Age, years. Mean ± SD	73.7 ± 9.5	75.7 ± 9.2	77.8 ± 6.2	79.2 ± 7.0	75.0 ± 7.7	73.9 ± 8.6	74.7 ± 8.1	73.6 ± 9.5	0.047[k]
<55	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	1.0% (1)	0.0% (0)	2.6% (3)	0.214[f]
55-69	22.2% (2)	42.9% (3)	5.3% (1)	6.2% (2)	27.1% (13)	32.3% (31)	30.8% (33)	28.4% (33)	
70-84	66.7% (6)	42.9% (3)	78.9% (15)	75.0% (24)	62.5% (30)	55.2% (53)	56.1% (60)	54.3% (63)	
≥85	11.1% (1)	14.3% (1)	15.8% (3)	18.8% (6)	10.4% (5)	11.5% (11)	13.1% (14)	14.7% (17)	

Missing pattern: Age N = 27, gender N = 27.
[k] Kruskal-Wallis test.
[f] Fisher's Exact Test for Count Data with simulated p-value.

Corresponding results were 5.9% to 79.7% in patients aged 70–84 years and 3.6% to 94.4% in patients aged 85+ years.

Crude revision rate was 4.0% for hemiarthroplasty and 3.2% for RTSA. After adjusting for age and gender, a higher failure rate was observed within the first 6 months for RTSA (revision probability at 6 month = 2.9% vs 1.0% in hemiarthroplasty, hazard ratio [HR] = 4.69 [1.95–11.29], $p < 0.001$), although a borderline lower failure rate was seen beyond 6 months for RTSA (revision probability at 3 years = 3.7% vs 4.2% in hemiarthroplasty, HR = 0.14 [0.02–1.02], $p = 0.052$). However, the revision risk of RTSA was not significantly different when averaged over all 8 years of follow-up time (HR = 1.34 [0.71–2.55], $p = 0.369$) (Fig. 2).

Discussion

Our data demonstrates a steady increase in the utlization of RTSA for the treament of fractures across the healthcare plan from 2009 to 2016. This coincided with a steady decrease in utlization of hemiathroplasty during this same time period. Utilization was roughly equal in 2014 when comparing the two, with RTSA

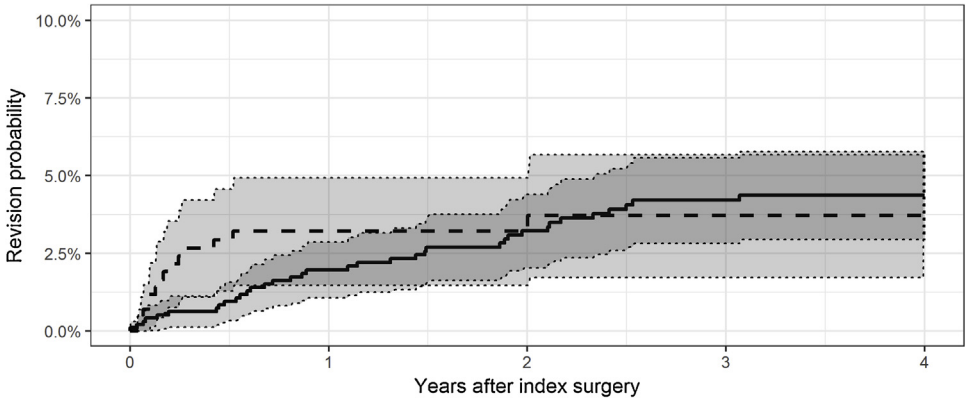

Fig. 2. Cumulative revision probability for hemiarthroplasty and reverse TSA. Hemiarthroplasty = solid line. Reverse TSA = dashed line.

outpacing hemiarthroplasty for the first time in 2015. In comparison, a recent publication from the New Zeland Joint Registry noted that hemiarthroplasty was surpassed by RTSA in 2012, though it should be noted this is a smaller patient population, with only 645 arthroplasties performed for fractures during the 16-year period of 1999–2014 [18] compared to our 1412 in 7 years. Rajaee et al [25], looking at data from the Nationwide Inpatient Sample, found the use of RTSA surpassed hemiarthroplasty in the US in 2013, though this was just in patients over the age of 65. Schairer et al [26] looked at the same dataset and reported a significant increase in the utilization of RTSA beginning in 2008, though when looking at patients of all ages RTSA utilization reached a peak of only 45.1% in 2013 (the last year of the data available). This increasing preference for RTSA coincides with the findings of Rosas et al [27], who analyzed the PearlDiver database and noted a near tripling of RTSA utlization in patients over 65 between 2009 and 2012. Interestingly, Rosas et al [27] also reported a decline in the percentage of fractures treated surgically during the time period of the study. It should be noted the aim of this study is not to examine the incidence of arthroplasties performed for fracture, which takes into account not only population size but also alternate methods of treatment, but rather the choice of hemiarthroplasty versus RTSA when the decision is made by the surgeon that the fracture severity is such that arthroplasty is indicated.

The impact of age upon the outomes of arthroplasty performed following proximal humerus fractures is unclear, although the results do appear to deteriorate with increasing age. The results of hemiarthroplasty in those with fracture have been shown to be less predictable when performed in those over age 70 [2,10,28]. It has been suggested that the utilization of RTSA for fractures should be reserved for those over the age of 70 [29], although some data demonstrates inferior functional outcomes in patients undergoing RTSA over 80 years of age for acute fracture indications [30]. Studies comparing the utilization of hemiathroplasty and RTSA in patient populations have found RTSA tends to be reserved for older patients [18,25,26]. During the period of our study, RTSA was performed in only 4.8% of those patients under 55 for a proximal humerus fracture. In comparison, RTSA utilization in older patients increased, with 79.7% in patients aged 70–84 years and 94.4% in patients 85 and older being RTSA in the last year of the study. As RTSA was increasingly utilized during the time period of our study, the average age of those undergoing hemiarthroplasty significantly declined suggesting surgeons are increasingly reserving hemiarthroplasty for younger patients who may be placing increased demand upon their shoulder.

Almost all studies have reported an increased utilization of shoulder arthroplasty for the treatment of proximal humerus fractures in women [18,31], although much of this disparity must be attributed to the increased incidence of proximal humerus fractures among women as opposed to patient selection [32]. A systemic review performed by Anakwenze et al [33] noted that over 90% of patients receiving RTSA for fracture were female. While a majority of patients receiving RTSA were female in our cohort, the ratio of male-to-female is lower than other studies. Whether this is due to differences in surgeon practice patterns or patient demographics is unknown. It is also interesting to note that our data demonstrated a relatively constant gender distribution for RTSA. However, as with age, subtle differences became apparent in gender distribution within the hemiathroplasty population with time, although this did not reach statistical significance. It may be surgeons are more likely to place a hemiarthroplasty into a male patient, perhaps due to concern for increasing demands that may be placed upon a RTSA in these patients.

Studies looking at complications and revision rates of RTSA performed for proximal humerus fractures have noted mixed results [12,15,17,18,31]. In a systemic review looking at the results of fourteen studies comparing hemiarthroplasty with RTSA, Namdari et al [34] reported a 4.0 times higher odds of post-operative complications with RTSA used to treat proximal humerus fractures. This must be balanced against the very real possibility that the tuberosities may not heal when hemiathroplasty is performed, a complication that has been shown to have a significant negative impact upon function [8]. Despite these findings, van der Merwe et al [18] did not notice any differences in revision rates between RTSA and hemiarthroplasty in their registry based study, and Sebastia-Forcada et al [17] noted a 40-month survival rate of 96.8% for RTSA and 80.0% for hemiarthroplasty. We observed a roughly similar crude revision rate between hemiarthroplasty and RTSA (4.0% and 3.2%, respectively, $p = 0.369$). It is interesting to note that the 6-month cumulative revision probability was 1.0% in hemiathroplasty and 2.9% in RTSA, while at 3 years the cumulative revision probability was 4.2% in hemiarthroplasty and 3.7% in RTSA. This suggests the risk of revision is higher for RTSA in the early post-operative period specifically, while the risk of revision for hemiathroplasty increases steadily over time.

The increased use of RTSA does appear to come at an increased expense [25,26]. In 2013 alone, the increased cost of treating proximal humerus fractures with RTSA compared to hemiarthroplasty was estimated to amount to over 15 million US dollars of additional expense [26]. Chalmers et al [14], however, determined that there were overall cost savings for RTSA when including expenses such as physical therapy. Further research in this area is clearly needed, especially given the recent focus on value in healthcare [35].

One strength of our study was the large number of surgeons and hospitals that contributed cases to the studied cohort, which increases the generalizability of our findings to other community-based practices. Another strength was the use of registry data to obtain information for the study. Information on the specific shoulder arthroplasty procedures was obtained from a dedicated Shoulder Arthroplasty Registry. This data source collects its information prospectively, and several elements are adjuticated either by trained research personel or surgeon leads, strengthening the internal validity of the presented information. In addition, registry data contains greater detail on the patient population, surgical indications, and procedures than typical surgical database studies, which rely on administrative data with limited clinical information [36]. It should be noted a dedicated ICD-9 code for RTSA was not available until the end of 2010, and as a result databases relying on codes are unable to distinguish RTSA from conventional TSA prior to this date. However, our registry has been able to accurately capture and determine the utilization of RTSA from its inception.

Our study has some limitations. While previous studies have demonstrated our patient population to be largely comparable both socioeconomically and demographically to coverage areas as a whole [21,22], inferences about the change in utilization of these procedures in other patient populations must be made with care from the current study findings. We did not describe the total number of all proximal humeral fractures in our patient population, including those treated nonoperatively, so prevalence or incidence cannot be ascertained. Furthermore, it must be noted that this study only looks at the role that shoulder arthroplasty plays in the treatment of complex proximal humerus fractures, and it is outside the scope of this paper to determine the effect that other procedures such as ORIF may play on arthroplasty volume. As such, classification of fracture patterns is not reported. As our study is descriptive in nature, inferences regarding age and gender and shoulder arthroplasty utilization cannot be made. Lastly, our registry does not collect patient-reported outcomes at this time, so

it is unknown if the increased utlization of RTSA within our patient population was associated with an increase in functional outcomes, although this has been suggested in prior studies [9,12–17]. Less is known, however, about the role that other factors may play in surgical decision making, such as surgical time and renumeration, and this information could be a source of future study.

Conclusions

In this registry-based descriptive study, we found that RTSA is being increasingly utilized for treatment of acute proximal humerus fractures when compared with hemiarthroplasty. Surgeons appear to be reserving hemiathroplasty for younger patients. At this early stage, there does not appear to be a difference in revision rates, though more time is needed to ensure the use of this more expensive prosthesis is justified or shows greater value.

Conflict of interest statement

None.

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